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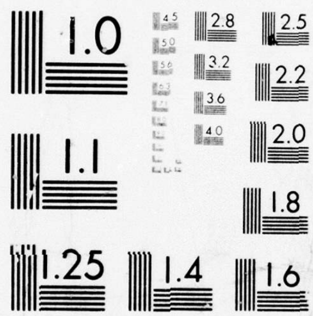

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INTEGRATED SIMULATION EVALUATION MODEL (ISEM) OF THE AIR FORCE MANPOWER AND PERSONNEL SYSTEM: REQUIREMENTS AND CONCEPTS

By

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August 1977

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This report develops a need, concept, and methodology for modeling the Air Force manpower and personnel system as a single, unified, integrated system which translates human resources into mission capabilities. The report lays the conceptual foundations for development of a large scale simulation model, which will integrate subsystems across functional specialties and evaluate performance from a total systems perspective of effectiveness and efficiency; thus follows the name: Integrated Simulation Evaluation Model (ISEM). The report explores the persistent features of the Air Force manpower and personnel system and systematically developes these characteristics into systemic functions, and finally into the basis for an ISEM. Theoretical modeling issues, as well as more practical issues; such as requirements for implementation are addressed.

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PREFACE

The contents of this technical report reflect the results of a basic research effort funded by the Air Force Human Resources Laboratory (AFHRL) under work unit 2313T201. This effort has used both AFHRL in-house resources and a contract (F41609-75-C-0035) effort with CONSAD Research Corporation and has extended over a two-year period. A first attempt to validate the concepts was funded by AFOSR in a contract with CONSAD Research Corporation. The results of this effort will be described in future reports.

TABLE OF CONTENTS

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INTEGRATED SIMULATION EVALUATION MODEL (ISEM) OF THE AIR FORCE MANPOWER AND PERSONNEL SYSTEM: REQUIREMENTS AND CONCEPTS

I. INTRODUCTION

The concept of an Integrated Simulation Evaluation Model (ISEM) of the Air Force Manpower and Personnel Systems is the result of a basic research effort at the Air Force Human Resources Laboratory. This effort begins a complex and difficult task of constructing a major analytical tool that can treat policy and decision issues that cross-cut traditional functional areas.

Previous efforts by the Air Force and by contractors related to this task have primarily involved building models and information systems adapted to specific subsystems within the personnel system or within the manpower system. The progress made in the various functional subsystems has improved the quantity and quality of information available to Air Force Managers and has no doubt improved the quality of decisions made by them within their functional areas.

The element that distinguishes the effort described in this report from previous work is the scope of the system for which a model is to be constructed. The ISEM concept involves a single *detailed model of the processes* by which the Air Force determines its human resources requirements and provides people to fill those requirements. ISEM involves the manpower function, which resolves a conflict between mission, technology, and budget into specific authorizations for skilled people to be placed in specific geographic (and administrative) locations. ISEM involves the personnel system, which manages the inventory of people within the Air Force to meet those requirements in the face of constantly shifting environmental variables. ISEM further involves the training and transportation pipelines, by which the inventory of people is modified in terms of skills and locations to meet changing requirements. Finally, ISEM will attempt to predict some of the environmentally driven factors such as accession and attrition rates whose variations are influenced by fluctuations in the national economy. Admittedly, the task is difficult and efforts of this scale have not previously been successful, but the questions which ISEM addresses are important, perhaps even crucial, and demand convincing analysis in today's environment where Air Force decision makers must do more with less. ISEM, as conceived in this technical report, would provide decision makers with information generated in a fundamentally different way. Present mechanisms for addressing high-level policy issues that transcend functional specialities (such as the problem of what the total force mix should be or the problem of fundamental changes in the retirement system) are the composite of functionally specialized information systems which may or may not be well integrated or interfaced. As a result, decisions based upon information produced by nonintegrated, preconnected, information systems whose elements were designed to address functionally specific activities, may produce unexpected consequences which could not reasonably have been predicted with present methods. In the long run, decisions can be expected to be no better than the information upon which they are based. What is needed then is an analytical tool that comprehends major policy issues within a unified conceptual framework.

This technical report documents the initial research efforts to develop a high-level policy analysis tool. Research thus far has concentrated on laying the methodological foundations required for constructing a simulation model. Simulation is virtually the only viable tool known which is capable of addressing the questions which ISEM seeks to answer. Simulation has very obvious applications in policy analysis. Since simulations imitate the behavior of systems and can greatly compress time by simulating the passing of years in literally a matter of minutes, changes in policy can be tested in the simulation model and the effects predicted before making changes in the real system. Thus, simulation holds great promise for providing the decision maker with a new valuable source of information on high-level policy issues. However, a full scale functioning ISEM is still years away. First, it was necessary to develop a sound theoretical approach to modeling the Air Force manpower and personnel system; it is this basic research that is documented in this report.

This technical report describes an approach to handling the problems described previously, as well as a wide variety of other problems that afflict the manpower and personnel systems of the Air Force. The sequel will elaborate on the technological approach taken; i.e., simulation evaluation of large scale descriptive models. It will discuss both the conceptual and the practical difficulties associated with applying the approach

to analyzing personnel force management problems. Further, this technical report will provide an initial description of the basic content that a simulation model must have to address (in a meaningful way) problems of the types discussed previously. This report will close with a discussion of the major institutional and technological problems to be overcome in implementing and using the simulation model.

The Technology Requirement

Over the past several years the Air Force has encountered a number of major technical and policy issues concerning the management of its personnel force that have yet to receive definitive or even convincing analytical treatment. For instance, such issues as the "total force composition" problem, the question of "optimal" force reduction policies, and several issues surrounding the trend toward centralization of personnel management have not been resolved. There seem to be several reasons for this, not the least of which are the problems of coordinating a very complicated analytical effort through a multiplicity of large, functionally segmented staff agencies. But more importantly, the problems are just very difficult—they cannot be force-fit into general problem classes for which solutions have already been devised. Rather, the solution techniques must be specifically tailored to the problems at hand. A brief review of the three aforementioned issues should make this clear.

A question that has been at the forefront of official concern is the so-called total force composition problem. The basic issue involved is the determination of a properly balanced allocation of the skilled personnel resources available to the Air Force among the active duty military, the two main reserve elements, and the civilian employee force. The underlying analytical problem is the development of a set of standards which operationally interpret the phrases "properly balanced allocation" and "available to the Air Force" in terms of mission requirements. From this follows the problem of consistently applying those standards to the complex of personnel resources.

Another important concern in recent years has been the realization that the Air Force lacks an efficient retreat strategy for absorbing force level reductions. Since 1968, the Air Force has absorbed a 37 percent reduction in personnel resources. During that time, there was little that could be done to systematically manage those losses to minimize the long-run impacts on the budget and on the ability to maintain force readiness. The problem was the lack of a way to measure the marginal efforts of the different loss rates across the whole spectrum of skills in terms of force response capability. Neither could an accounting be made in terms of the human capital (i.e., the future productivity of people due to an Air Force training investment) being liquidated at no return.

A third significant policy issue that, essentially by default, has not received sufficient analytical treatment is the trend toward centralization in the management of human resources. This question has at least two aspects. One is the problem of explicitly determining the realized payoffs of the centralized resource management system, which has developed around extensive data transmission, storage, and processing facilities. There are some obvious potential benefits to be captured from centralized management; e.g., quicker resolution of allocational conflicts, increased information utilization in decision making, intensifying goal consensus of system operators, an increase in the number of alternatives available for policy trade-off studies, reduction of processing time for personnel actions. However, it is not clear that the centralized management systems that have evolved function efficiently. (Indeed, it is not even obvious whether or not internal system changes improve or degrade system performance in terms of external measures of Air Force mission performance capabilities.)

In addition to these three specific problems, there is the more general problem of conflicting behaviors within the systems. Quite often, it is remarked that the objectives of even rather high-level organizational units within the manpower and personnel systems have divergent effects on the achievement of the same mission goals. For the particular systems under consideration, it might be more noteworthy if this were not the case, given the diversity and extent of organizations involved in controlling the personnel force. For instance, in the current structure, there is a conflict between the maintenance of low attrition rates in technical training and the achievement of aggregate recruiting goals. Low attrition rates in technical training can be achieved by enlisting only high aptitude recruits; however, this significantly reduces the potential supply of recruits and thereby conflicts with recruiting goals. Similarly the goal of promotion equity across technical specialties is hindered by rapidly shifting manpower requirements caused by the introduction of new technology. New technology may make some skills obsolete and change the demand for others both inside and outside the Air Force. This leads to differential

attrition rates and great difficulty in allocating promotions across skills. A more subtle conflict appears to exist between the operational readiness requirements of Air Force combat units and the peacetime goal of developing the skills of the personnel force. (Indeed, this can be extended to a more basic personnel management conflict between "deepening" versus "broadening" skills.)

Two commonalities are shared among these illustrations: (a) the conflicts in objectives and behavior stem not so much from irreducible resource constraints as from conflicts between the incentives that face the people who operate functional subelements of the system, and (b) they occur between functionally separate organizations. The conjunction of these two common qualities suggests either that the designers of the centralized management systems had difficulty incorporating and coordinating the incentives that were established within the various systems; or that, after initial design, the systems evolved separately in response to different perceptions of environmental changes; or that conflicting incentives were implanted for particular control purposes. This last alternative, while exceedingly interesting in concept and definitely relevant in some conflicts, is unlikely to be the general case because of the diverse nature of the inconsistent behavior encountered. More probably, some combination of the first two may be the source of most manpower and personnel management systems conflicts. Both aspects of this issue of centralized management; e.g., (a) determining real benefits, and (b) conflicting objectives–seem to derive from an inability to establish a formal baseline design that comprehends all functional elements required to furnish skilled labor services as an input to the Air Force mission process.

These issues are clearly important to the proper management of the Air Force. Currently, there exists no means to either analytically determine an optimal solution to the problems or to demonstrate (prior to the great victory or catastrophe on the battlefield) that the ways in which the Air Force is coping with them are adequate. If the problems have a common denominator, it would seem to be this: that policy makers and analysts have no way to establish the proper relationships between the component parts of the manpower and personnel systems and their marginal contributions to the Air Force mission. This observation, is neither surprising nor a criticism of the policy makers. For one thing, there is no incontrovertible objective measure of Air Force mission performance. Secondly, the systems involved seem to have a bewildering complexity of a type which confounds intuitive or fragmented approaches. Yet the fact that the Air Force personnel system annually consumes over ten billion dollars indicates that a substantial effort should be made to develop techniques which will resolve these problems.

The Air Force Manpower and Personnel Functions Represented in a Unified System

One of the problems with the term "system" is that it evokes no definite image or concept. Indeed, there is almost no context in which the term cannot be applied in some sense (i.e., it is what semanticists call an omnibus word). Since this report uses the word "system" with great frequency, it is perhaps useful to explicitly state the sense in which it is used–to wit: the term "system" will be used to designate a class of objects, processes, and relationships that can be associated with one another by a common purpose. This teleological approach to the term is useful, since it allows the definition of a total system by the specification of the characteristic property of a class. Moreover, since the characteristic property is the purpose, the system definition forms the foundation for its meaningful evaluation.

This then is the basis for casting the various functions involved in managing the personnel force into a unified framework suitable for modeling and evaluation. The easiest way to do this is to start with the most obvious supersystem and pare off parts not related to the purpose at hand; what will be left will be something nominated the Air Force Manpower and Personnel System (AFMPS).

The relevant supersystem is the Department of the Air Force (DAF). For the purpose of this discussion, the DAF mission is analogous to a production process, the output of which is aerospace combat capability. It should be immediately noted that the DAF neither directs nor controls the combat deployment of Air Force operational elements; rather, its activities are strictly confined to developing and maintaining force readiness. The inputs to the DAF production process can be segmented into the broad categories of human and nonhuman capital services. Within each category it is possible, of course, to define many classifications of services based on characteristics of interest, as they contribute to the process in different ways.

Looking exclusively at the management and utilization of human capital inputs, it is possible to

establish two distinct classes of associated administrative activities: (a) class 1—those activities that direct and control the allocation and application of human capital to nonhuman capital to accomplish particular mission tasks, and (b) class 2—those activities that translate Air Force mission objectives into human capital requirements and then attempt to provide the required mix and quantity of human capital inputs as required for the class 1 activities. The purpose of the AFMPS is to accomplish the activities under class 2.

In order to sensibly analyze the AFMPS as a system, it seems useful to divide the world into six distinct categories of objects: (a) those things not in the AFMPS, (b) those things in the policy information control (PIC) subsystem of the AFMPS, (c) those in the personnel force structure (FS) subsystem of the AFMPS, (d) the resource mobility mechanisms that transform activities in the PIC into changes in the FS, (e) those things which exogenously affect the PIC, and (f) those things that exogenously affect the FS.

This gross classification structure is based essentially on the physical nature of the various class members. The types of elements found in PIC might be named "data flows," "data processors," "policies," "decision points," "skill classification systems," "job classification systems," and "goal structures." The PIC is the administrative overlay of the AFMPS. It receives information about the state of the FS, and acts on that information so that future status reports show closer conformance with the goal structure embodied in the PIC. In conformance with the Air Force organizational structure, the PIC can be functionally segmented into the manpower system and the personnel system. The chief purpose of the manpower system is to assess the mission of the Air Force in terms of tasks to be performed, and to convert the mission into organizational requirements and labor service requirements to fulfill mission tasks. In this sense, it reveals the derivative demands for human capital inputs to the DAF productions process. These demands are based on exogenously supplied criteria, such as a scenario for the most demanding war the Air Force will be required to support, the Five Year Defense Program (FYDP). The job of supplying the demands posed by the mission, as revealed by the manpower system, falls to the Air Force personnel system. The personnel system, acting with the training management system and within legal and budgetary constraints, directs the development, maintenance, and allocation of the complex of resource pools embodied in the personnel force structure. In general, the PIC initiates all purposeful behavior within the AFMPS.

The FS is composed of elements; such as people, their relationships to the Air Force organizational structure, their embodied skills and work capacities, and the persistent behavioral features of particular subgroups of people within the system. Obviously, it is between elements of the FS that actual personnel flows occur, and within FS elements that the capacity to accomplish mission tasks resides. The FS is composed of about a million people classified in as many different ways as is convenient for the various decisions that must be made. One basic way of categorizing the FS is in terms of active duty military, inactive reserve military, and civilian components. The military force can be broken into officer and enlisted forces; officers can then be separated into rated and nonrated; and all force components can be crosscut by hundreds of skill classifications. Further, the active officer, enlisted, and civilian components each have separate pay grade structures, as do the reserve forces. Other important ways of subdividing the gross personnel force structure include geographic location and unit of administrative control. It should be noted that each of these categories is tuned to some particular management problem faced by the PIC. Another way of deriving subclasses within the FS is to establish job groupings, with homogeneity of tasks actually performed as a characteristic property, and populate each subclass with all people having that property. This last classification system is of particular interest, since it provides a basis for aligning the force structure classification system with the input requirements of the DAF production process. Also, to some degree, it conforms to the basic idea behind the manpower functional accounting system.

The resource mobility mechanisms include those things that the PIC activates to actually effect changes in the FS. In a very real sense, most of the outputs of the PIC take the form of verbal or written decrees. Only indirectly do these outputs actually change the state of the FS. For instance, permanent change of station (PCS) orders may initiate and direct personnel flows, but aircraft, trucks, and automobiles actually move people. Too, the development of a trained personnel requirements document does not imbue people with job skills—courses, classrooms, instructors, instructional aids, and student hard work—do that. The elements of this class act as the channels through which personnel flows occur, and are the basic means of resource mobility in the Air Force. Indeed, it is the ability to establish proper connections, the flow rate capacity, and the classification and leakages of these training and

transportation "pipelines" that ultimately constrain the adjustment of the force structure to PIC decrees. This perspective implies that the substantial nature of the mobility mechanisms in the operation of the AFMPS, takes the form of the time requirements, misdirections, and attrition rates involved in moving personnel resources between the various organizational coordinates of the FS.

Exogenous effects transmit their impact into the AFMPS through the PIC, but are in no reasonably direct way influenced by any element in the system. For the purposes of this research, such things as the various requirements scenarios, overall budget constraints, and legal strength limitations on force components should be considered as exogenous inputs to the PIC. The key exogenous inputs to the FS are (a) the various internal-external labor market interactions that determine the supplies of recruits with particular aptitudes, and (b) the retention rates of trained personnel with specific skills for various force components.

At a generalized level, this functional description and taxonomy of the AFMPS classifies the elements system to facilitate modeling. However, the chief utility of this level of generalization is limited to promoting conceptualization. While this is no mean task, rather it is among the most important and difficult modeling task, a generalized model in and of itself is of little value to the decision maker. In developing this generalized model into a viable information asset for decision makers, the technological approach employed greatly influences the potency of the final product.

II. THE TECHNOLOGICAL APPROACH

Normative versus Descriptive Modeling

It is part of the mission of the Air Force Human Resources Laboratory (HRL) to probe and expand the limits of application of the emerging technology of system modeling to various aspects of the Air Force manpower and personnel system. While acting upon this mission, scientists at HRL have directed their attention to modeling specific processes and subsystems that are embedded within the very complex organizational system that manages manpower and personnel activities for the Air Force. The results of these efforts have been two basic types of models—normative and descriptive. This subsection will discuss each in turn with respect to potential application to large-scale modeling and evaluation of the AFMPS.

Normative models are those which, as their primary output, produce specifications of system behavior that is in some sense desirable, relative to the defined goals of a particular operating process. Examples of normative models developed by HRL scientists include the officer effectiveness report (OER) "tilt" mechanism model (which eliminates the buildup of particular types of bias in the promotion evaluation process) used at the Air Force Military Personnel Center and the Total Objective Plan for the Officer Procurement System (TOPOPS) model (which defines an optimal officer procurement program cost-quality tradeoff). In general, the effective development of a normative model requires that the system of interest be conceptually distinct and limited in terms of its goals and the effects of its operating processes. For example, in terms of the OER tilt mechanism, the model essentially operates to assure that the fatigue of promotion board members does not countermand a specific promotion equity goal. The effect of the model is completely transmitted through that goal. All other model effects are isolated from the Air Force by the closed promotion board. Ideally, if a normative model is to be applied to any sort of large-scale system, it should be during the initial design of system operating models. Then the normative model can explicitly incorporate all of the objectives of the new system and direct its behavior to seek those goals. In this case, the normative model becomes the system baseline of operation.

In practice, of course, new organizational systems are seldom designed from the ground up, and normative models are introduced as decision aids to enhance the performance of particular processes of multiprocess systems. There are two related difficulties in this practice. One is that models for which optimal behavior has been worked out can only rarely reflect the true complexity of the real world, unless the real world is, as described previously, constructed around the model. This difficulty is most often overcome by restricting the application of normative models to those subprocesses with performance characteristics that can be measured in unambiguous numerical terms. Doing this, however, leads to the second difficulty; i.e., that it is seldom clear what effects the introduction of normative models (that optimize against the concrete subprocess goal) have with respect to the more basic and abstract goals of the entire system.

The development of descriptive models reflects a fundamentally different application of modeling to system improvement. Rather than attempting

to prescribe what a system ought to do, descriptive models try to formally represent the structure of the system as it is. They are used to generate hypotheses about what the system does or will do. Essentially, descriptive models organize into a meaningful format all important information about the current operation of a well defined system. This type of model may be formulated in many ways. For instance, a descriptive model may be a statistical relationship, a set of simultaneous equations, a sequence of difference and/or differential equations, a graphical display, or simply a verbal description of the operating principles of an organization. Exactly how such a model is formulated depends upon three basic factors: (a) the specific purpose of the model, (b) the nature of the system being described, and (c) the degree of understanding of the system processes and relationships possessed by the scientist constructing the model.

In general, there are three good reasons for constructing explicit descriptive models of systems. (This is as opposed to the internal models of systems which analysts must hold within their minds. If the models are not explicitly set forth, only fragments are revealed to critical review.) First, such a model reveals the analyst's perception of the system in conjunction with some particular purpose; this, of course, allows critical assessment of the results of any given analysis. Second, a descriptive model can reduce the uncertainty of predictions of the response of a system to external perturbations, internal failures of performance, or basic inconsistency in internal configuration with respect to the function under study. How this result is accomplished depends essentially on the form of the model–it may range from finding the solution to a set of equations, to extrapolation using statistical relations, to simulation of the operation of system processes over time. The third reason for explicit and complete models is to facilitate numerical computations by providing a consistent framework for measurement and comparison.

The conjunction of the purpose to be served and the nature of the system under study determines the type of descriptive model to be formulated. This report is concerned with the problem of usefully modeling the AFMPS–this system is a complex, hierarchically structured organizational system. In some ways, this is a most difficult type of system to represent in a model. The reason for this is that the behavior of such systems is largely nonintuitive. Even if we completely understand all of the subprocesses of the system, the way in which the processes are structured to interact has strong behavioral implications which cannot be predicted by *unaided reasoning*. Thus it is often very difficult to statistically model the behavior of information-feedback control systems. On the other hand, it turns out that the types of information that are critical to effective representation of such systems often can be obtained with an inherently high level of accuracy. The way this information can be used will be discussed in the next subsection.

It should be clear that it would be meaningless to develop a normative model of the AFMPS prior to development of a rather complete descriptive model. The system is so convoluted and extensive that to fit it in a form suitable for optimization analysis would require a transmogrification of its characteristics. Many features essential to its behavior would surely be left out or changed beyond recognition. Thus, descriptive modeling should be developed prior to normative modeling so that (a) a full account of cause and effect relationships can be established, and (b) the goals and constraints on goal attainment are clearly specified. The latter permits a more realistic representation of the system. The former gives the analyst a basis for sealing off adverse effects of his prescriptions from other parts of the system.

Information-Feedback Control System Model

The literature of systems theory provides numerous taxonomies for classifying systems. Generally these taxonomies are necessarily somewhat simplistic and suggest firm guidelines for classifying simple systems. However, the AFMPS is exceedingly complex and fits no systems taxonomy precisely; rather the AFMPS fits rather well the feedback class of system, a type common to most taxonomies. Feedback systems vary in complexity from simplistic thermostat systems controlling temperature to complex socio-economic systems which control and influence multitudinous variables. Essentially feedback systems provide for some type of system reaction to conditions within or external to the system–for a simple thermostat system this might be an air conditioner switching on in response to warm room temperatures, or for a complex system like the AFMPS this might be increased training of new recruits in response to high attrition rates. Naturally, the AFMPS is a complex system consisting of many feedback subsystems as well as many subsystems of other types. However, it is this persistent feature of responding to conditions that causes complex socio-economic systems to be taxonomified as feedback control.

The chief feature of this class is a continuous regenerative process whereby environmental changes cause decisions to be made which change the original environment which stimulates new decisions. The behavior of such systems, whether they take the concrete forms of electronic flight controls, biological organisms, or social organizations, is characteristically nonlinear and oscillatory. Indeed, for engineering-type systems, the design problem is essentially that of properly damping and shaping this type of system response to design objectives.

The main factors which condition the behavior of organizational information feedback control systems have been found to be the information system structure, time delays, and the policy structure. The structural and delay sequences that characterize a particular organization give it some synergistic behavioral aspects not normally considered in management systems analysis. Phase shifts, periodicity, resonant frequencies, policy bandwidth, and stability appear to confound predictions about system performance. See Forrester (1968) for elaboration on systems terminology.

Experience with information feedback control systems indicates that, with the exception of a few key points of leverage, models that are properly constructed with respect to the noted three factors are relatively insensitive to variation in parameter values in replicating the dynamic behavior of their real-world correspondents. This is because of the goal-seeking, self-correcting nature of such systems. Even if exact adjustments are incorrect within a model, it incrementally seeks an objective state that corresponds to the goals sought by the real system.

Time delays are particularly important in information-feedback control system behavior. System response to environmental changes can be amplified by the simple fact of variable delays in information flows. Further, delays themselves can be frequency sensitive. They may amplify the effects of external disturbances that occur within a certain range of frequency and attenuate them outside that range.

The study of the AFMPS (as an information-feedback control system) requires a careful definition of the concept of a policy so as to distinguish between policies and decisions. Decision processes transform information into action; policies are rules which govern the use of information in decision processes. Implicit in any policy is the concept of an objective or a desired state of affairs to be achieved. Policies establish with varying degrees of specificity the information relevant to a decision, the timing of its use, how it shall be weighted in alternative action selection, and the range of alternatives that can be considered for selection. Policies explicitly or implicitly determine, often with profound effects, how the tradeoff between short run versus long run objectives is to be made. In terms of information received by a policy-restricted decision maker, decisions that attempt to control toward long run goals often create "worse-before-better" sequences. This naturally conflicts with short run goals, and if the purpose of the policy guidance is not visible or if the incentive system is not weighted in consonance with long range goals, the decision maker may be led to circumvent policy restrictions. This can be highly dysfunctional to the attainment of the purpose for which the organization exists.

If the behavior of the AFMPS as a whole is greatly influenced by its information-feedback control system features, then explicit information about these aspects of the system should have a prominent place in a model attempting to describe its behavior. This is not to say that nothing else is important in the functioning of the AFMPS. For instance, the management styles of the leaders who operate within the confines of the AFMPS may have a considerable impact on the particular path that the system takes with respect to some arbitrary operational measure. Management style is just one example of the influence of people within the system; collectively these influences are the "human factor."

This "human factor" transmits its effects into system behavior in three ways: (a) through incorporation in the system policy struture, (b) through effects on the efficiency of human factors of the system (by effects on motivation, for instance), and (c) through novel or creative action selection in decision situations. The first of these can be incorporated directly into a model of the system structure. The second probably can be represented only by essentially "brute force" techniques. Novel or creative behavior is definitionally impossible to represent in a model. It is one of those situations that limits modeling and extrapolation of any kind–it is similar to the situation explored by Karl Popper (1965). In studying the logic of scientific discovery he concluded that there is none. One cannot be consistent with the axioms of probability and model novel or creative behavior as equivalent to random behavior; i.e., as a probability distribution over a space of events (action selections). This is because the essence of novelty is the creation of new events outside the original universe of discourse.

Yet the fact that novel events are not predictable does not obviate the usefulness of a descriptive model of the AFMPS. Rather, if the model is properly conceived, the possibility of creativity in manpower and personnel decision making makes the model even more important. In particular, the model should formulate in a consistent computer simulation framework the factors which limit the freedom of action of decision makers. This means that the model should identify those points of leverage where good decisions are critical and should point out those components of behavior where the system bandwidth is so narrow as to attenuate the effects of any short run policy changes. (The concept of bandwidth is taken from the theory of linear systems as developed by electrical engineers. It is not technically correct to use the bandwidth concept for nonlinear systems as are at hand. However, the notion of change-resistant behavioral patterns is quite relevant to nonlinear systems.) The model will then allow an analyst to map from an unbounded domain of action selections to a bounded range of results—to test the effects of new alternatives when played against the information feedback structure and the real resource constraints on the system behavior. Rather than modeling how managers drive organizations, this effort focuses on how the organization drives management.

System Representation

Because the policy-information-control system of the AFMPS is bureaucratically organized and administered, it is conceptually possible to localize responsibility and authority for each action or response requirement explicitly recognized in the system goal structure. The fact that many important parts of the system are designed around computer based information processing and transmission facilities makes the proper assignment of decision tasks especially easy to determine. Since this is possible, it is also possible to determine the sequence of decisions and connecting flows of information which initiate the follow-up on most purposively caused changes in the personnel force structure. Further, with each action sequence, specific action times can be specified—time required to collect data, to process it into decision relevant information, to evaluate and choose an alternative, and to transmit the decision results to other parts of the system.

The fact is that in a formal bureaucratic organization relatively few individuals participate in any given decision sequence as compared with, say, informal organizations such as commodity markets. This isolation of function has important implications for system representation. Individual decision flows can be explicitly and discretely represented as sequential processes. Again, this is a contradistinction with such things as competitive market structures which are commonly modeled using Walrasian-type simultaneous determination or extremely sophisticated game-theoretic formulations. Rather, the internal decision structure of the AFMPS can be effectively represented by a nontheoretical structural analogue based strictly on a principle of explicit correspondence; i.e., that each important information flow and each decision node and each explicit policy in the AFMPS will have an empirically interpreted correspondent representation in the model. This is feasible because of the "finiteness" of the parts of the AFMPS that it is conceptually possible to represent. Discussion of ways of dealing with the practical problems of implementing this type of representation is deferred to Section III, where a preliminary description of ISEM content is presented.

The representation of the personnel force structure is tailored to the evaluative framework of the model. In actuality a set of force structure models are embedded in the PIC portion of the AFMPS. These models, defined by management categories: such as skill/skill level, grade, year group distributions, location, and force component, form the cognitive structure of the control system. They determine which attributes of the personnel force are managed and which attributes freely adjust in response to management action. An important aspect of this effort is to expand the description of the force structure to allow evaluation of some of those variables which do adjust without explicit control within the AFMPS.

The first step in modeling the force structure is to develop a unified cross-stratification by the important force categories now used to manage personnel resources. This is important to the feedback control system view of the model in that it allows detection of the responses and response lags in directed changes. This leads to direct evaluation of control effectiveness and efficiency by establishing the linkage between a decision process and its result through the control action transmission mechanism of the system (i.e., the training and transportation pipelines).

Subsequent to this, other representations of the personnel force can be constructed in terms of variables that freely adjust as the variables of the cognitive structure are controlled. In particular, the personnel force could be modeled in terms of variables that relate to the long run operating costs

of the Air Force, the efficiency and effectiveness with which it trains its people, and its ability to support defense contingencies. How this might be done is discussed later.

Representation of the training and transportation pipelines of the AFMPS is perhaps the most straightforward problem to be encountered in this effort. The only real problems that arise in this context are the multiplicity of channels from point-to-point in the system and channel capacity limits. In the modeling methodology described in Section III, even these turn out to be fairly minor issues. One characteristic that should be recognized is that variations in flow in the pipelines have definite impacts on manpower requirements and, therefore, on the allocation of personnel resources. Second and higher order effects on the personnel system are generated by changing pipeline throughput. If the changes are fairly large, one can envision that this might be a source of significant cyclical behavior in the personnel system.

If the problem of establishing internal resource mobility restrictions implied by the training and transportation pipelines is relatively straightforward, the problem of representing the limitations on obtaining personnel from the national economy is a significant modeling issue. One of the key facts about the AFMPS is that it is a very distinct internal labor market within the national economy. It has always had characteristic ports of entry and exit through which most Air Force members pass for their tours of service. Further, the terms and conditions of Air Force labor service contracts are enforced by criminal statutes.

For a variety of reasons, including specificity of many of the skills within the organization and the peculiar nature of military duties, the Air Force has chosen to compete for new personnel from a restricted population segment that contains mostly unskilled workers. It also, of course, competes in a wide variety of skills markets within the external economy to retain those trained people who have skills that are transferable to the civilian economy. (By this it is not necessarily meant that the Air Force only loses aircraft mechanics to similar jobs with civilian airlines—it is also the case that the work habits, general skills, and good health of most Air Force personnel make them potentially valuable employees in many occupational settings.)

The ability of the Air Force to acquire and retain a sufficient number of personnel to accomplish its mission is greatly influenced by its selection and compensation policies. Since the Air Force directly employs only about nine-tenths of one percent of the national labor force, there are obviously many more resources potentially available to the Air Force than could be properly used. The acquisition problem facing the Air Force stems largely from the externally and internally imposed policies, such as (a) those which engender the negative benefits of military life, (b) the relative inflexibility in its compensation program, and (c) age and aptitude requirements that disqualify most of the civilian population from entering the service. All of these factors are quantitatively important only when viewed in relation to the conditions in the national economy. It is this relationship that must be captured in ISEM. The way this is approached in the ISEM concept is first to develop a model of the individual's decision structure at the ports of entry and exit for the Air Force. This will essentially structure the content and timing of information use in deciding whether or not to join or continue in the Air Force. The decision model is the basic interface between the AFMPS and the national economy. Then, a model will be constructed to represent those aspects of the national economy that generate the information that enters the accession/continuation decision.

Simulation Analysis

It is quite clear that ISEM will include a large and complex descriptive model; its construction will require a considerable commitment of scarce research funds and effort. While one can distinguish various noteworthy modes of utilization of ISEM that would return significant benefits, all of the benefits derive from a few important features of simulation analysis.

First, simulation offers the opportunity to compress the time in which events occur. Under the current ISEM design philosophy the time compression will be a factor of around 5 to 15 thousand, so that a full five years of the future could be simulated in three to eight wall-clock hours of computer time. (This need not be the case for simulation—the State Department is reputed to have a highly detailed computer simulation model of the 1973 Arab-Israeli war with run times longer than the actual war.)

It is also important that everything occurring in the simulation model is directly observable—one can monitor the evaluation of variable states to any desired level of detail. Also, ISEM is not a statistical model with uninterpreted parameters. It is to be a symbolic analog of the real structure.

Every decision, every policy, every information flow, every resource pool, every personnel flow, and every action time requirement that is symbolically represented in the model will be an interpreted correspondent of something in the actual AFMPS. If an analyst disagrees with some particular formulation of something that is represented in the model in terms of its conformance with reality, he may experiment with alternative formulations. The only part of the model, for which this may not be the case, will be the representation of the national labor market. The final form of this portion of ISEM is far from a settled issue—however, any consistent summarization of the ensemble of available demographic and economic data will be an improvement over the current situation. Section III suggests an approach to the problem that may be a significant improvement in providing a useful market structure.

These two factors, time compression of dynamic behavior and observability of internal processes, can be exploited in many ways depending upon the objectives of the users. Orcutt (1963) listed six "obvious" uses of simulation models: (a) forecasting of macro-behavior; (b) predicting macro-consequences of alternative (exogenous) actions; (c) conducting control and stabilization studies; (d) provision of aids to teaching, training, or achievement of understanding; (e) conducting sensitivity studies as a source of research guidance; and (f) facilitating testing and estimation.

ISEM must be constructed to permit all of these uses. The full-scale, empirically interpreted model will be based upon an extensive and highly organized data base. For example, to promote forecasting of macro-behavior and predicting macro-consequences of alternative actions, an effort will be made to map out as much of the management information network as can be detected from examination of the documentation of the formal system, by survey techniques, and by direct observation. Structural, qualitative and quantitative information will be "callable" and available for graphic or tabular display in an interactive mode through a data base management system. It will be as complete a system baseline of reference as can be constructed. Such a data base will be intrinsically useful for design of system changes and for estimating the staff costs of each function in the AFMPS.

Perhaps a more valuable use of ISEM can follow from studies of the internal control system. These studies will identify the policies and information flow patterns that cause unnecessary oscillation (for instance, periodic undershoot and overshoot of counted force levels with respect to skill-by-skill force level goals). Simple adjustments might be made in the timing of information use that will result in significant changes in system performance and lead to a more stable and/or less costly force. An extensive and long-term analysis using ISEM would be a study of the resonant response of the AFMPS to technical and procedural adjustments of both individual policies and sets of policies. While it is the case that the AFMPS is evolving, it is also true that it is easier to change the model than it is to change policies within the system. If the AFMPS is properly monitored, it will be possible to update the descriptive model at least as fast as the system formally changes. An interesting question impacting upon the validation of ISEM will be the possibility that many discrepancies in the behavior of the model and the system will derive from "illegal" ("adaptive" might be a better word), or out-of-channel decision behavior occurring in the system.

ISEM should be an excellent tool for training and for research analysis. In a training mode, it could be used to teach system operators and users how to function effectively within the system. ISEM could function equally well for research guidance and analysis. Given that the model will reveal the points of leverage in the AFMPS, one could assess where changes are likely to be most cost-effective. This should greatly assist managers in the optimal allocation of the very scarce research funds available for human resources management problems.

Perhaps the most important envisioned use of ISEM, however, is an attempt to develop a framework for evaluating the operation of the AFMPS as an overall system due to its ability to facilitate testing and estimation. If the total system output can be valued, then because of the integrated structure of the descriptive model, it will be possible to impute marginal values to all internal functions of the model in terms of the overall value structure. The question of how one values the output of something like the AFMPS depends upon the point of view of the analyst. For instance, a labor economist working on civilian manpower problems might look at the output of the AFMPS as a stream of trained people appearing at its ports of exit—to him, all of the labor services expended in the Air Force mission will be virtual waste. To the Air Force analyst, the converse will be the case. A more detailed discussion of total system evaluation is taken up in the following subsection. In any case, the object for evaluation is the mechanism through which the AFMPS influences the composition of the personnel force structure.

Thus, from two noteworthy features of a simulation, time compression of dynamic behavior and observability of internal processes, at least six types of applications offer significant benefits to the user. However, the information benefits of a simulation may be greatly increased by the evaluation tools available for assessing the results of a simulation.

System Evaluation

Efficiency and Effectiveness Measures. A key feature of the ISEM concept is the inclusion of an extensive package of evaluation techniques that will monitor and analyze the flood of data resulting from a simulation exercise of the descriptive model. This evaluation module will mesh with the descriptive model in that it will receive output from the simulation—it will not automatically feed back results of the evaluation to modify decision making in the model. The purpose of the evaluation module is to reduce the outputs of the simulation to a limited number of indices of performance that are indicative of the operating efficiency and effectiveness of the AFMPS at both the microlevel and at the level of overall macrosystem behavior. There is no single concept of efficiency or effectiveness that will completely characterize the microlevel status of the AFMPS. Rather, an extensive range of concepts will be proposed to measure the operating characteristics of the various subsystems. As experience with the model (and with tests of the indices on the modeled system) accumulates, a history of the values of these measurements will be recorded for a wide variety of operating modes of the system. With these data series, ensembles of "normal" operating indices can be determined for the AFMPS.

When the concept of efficiency is used here, it is referring strictly to resource consumption efficiency of the AFMPS. In order to properly measure efficiency, of course, a fully developed cost accounting system will be incorporated into an evaluation module. This accounting system will monitor all activities of the AFMPS modeled within ISEM and record and accumulate the cost flows initiated by the AFMPS. This will include not only the costs of hiring, paying, promoting and separating people; it will also include costs of training and moving people and reflect the differential costs of stationing people in different locations. The system will also account for the various administrative costs of managing the AFMPS. The underlying philosophy of this system will be to reflect the rate of expenditure of financial resources that follows from any mode of system operation, personnel force composition, and force positioning. This type of costing system will be most useful in comparing the relative costs of operating modes of the AFMPS that have outputs judged to be equally effective.

The effectiveness of the AFMPS in performing its mission can be measured against many criteria; measurement will be achieved by several techniques. One technique will be to analytically establish a theoretically ideal model of operation. A classic example of this concept is that of the Carnot engine of thermodynamics which is a theoretical engine of absolute efficiency. One can conceive of Carnot engines for the AFMPS. For example, a training system that is ideal in the sense of minimizing waste might have all training cumulative toward job requirements. Clearly, no system in the real world could attain this sort of ideal—the implications of attaining it pose significant conflicts with other system objectives. For instance, no cross-training could occur, and since there are differential requirements for grades in each field, there would have to be differential promotion opportunity across career fields. The system is currently managed to enforce equal promotion opportunity across career fields, and this forces people to be cross-trained out of their area of career specialization to achieve promotion equity.

Another approach to measuring effectiveness is to compare relative operating characteristics of the system under different management regimens. For instance, the effectiveness of competing training management systems could be compared on the basis of the number of months in a year during which the training output is within $\pm X$ percent of the existing requirement at the time of course graduation. Training pipeline management systems might be compared on the basis of the months within the year in which the training output is within $\pm X$ percent of the requirements that were projected to exist at the beginning of the management horizon. These types of effectiveness indices would allow ordinal measurement of subsystems effectiveness.

The point is that any number of these types of subsystem level performance indices could be developed for diagnostic purposes. Further, they could be correlated with overall system performance measures to find potential cause-and-effect relationships. These types of relationships would allow the development of improved force management incentives that tie directly to overall system performance rather than subsystem performance. The key is to find appropriate macrolevel performance indicators.

Macro-System Effectiveness Measures. The basis for the evaluation of the overall performance

of the AFMPS is the statement of purpose which defines the system: the AFMPS determines the requirements and supplies the people who deliver skilled labor services to the Air Force mission process. ISEM could be used to measure the AFMPS macroperformance in terms of its capacity to support the initial surge and extended drain of contingency requirements. This can be done by first describing a range of combat scenarios as partially ordered sets of skilled man-year loadings required in specific geographic locations (perhaps in the form of program evaluation review technique (PERT) type networks that cycle after initial buildup for steady state mission performance). From here the system evaluation can be done in two ways.

From one standpoint the model could operate under a wartime decision logic to fill the scenario requirements. The model would generate a personnel buildup trajectory using its dynamic simulation structure. The resulting trajectory could be compared against the requirements trajectory and various measures of effectiveness devised. This approach has at least two significant deficiencies. First, it requires the entire model behavior to be driven by a single contingency scenario. The buildup trajectory would be a function of the initial conditions and wartime policies. It would say little about how the peacetime policy set causes force capability to evolve. This work of detailed analysis could be performed, of course, and it might be useful for the development of wartime policies. It is doubtful that it is a good way to evaluate the AFMPS, however, since the AFMPS is designed for force development, not force employment. The second deficiency of this approach is that it is very wasteful to run a large-scale model to full term to obtain what is essentially a single data point.

A second approach would be to operate the simulation model under a given set of peacetime management policies. These policies would guide the model dynamics as long as they maintained reasonable control over force structure evolution. At any given point in simulated time, the force structure state would be the initial conditions from which the first phase of any contingency must be met. Thus, at any time, one could stop the descriptive model process (or dump the model content to tape for later analysis) and assess the state of the personnel force in terms of the most demanding war scenarios the Air Force is expected to fight. This would be done using the evaluation module. The module would contain as one of its components an algorithm to evaluate the maximum capabilities of a force-in-being under wartime priorities and policies.

The response of the system would be a function of the initial quantities of skilled labor services in the force, the capacities of the resource mobility system, the information about the force used in allocation decisions, and the relative priority of the contingency in relation to all other missions. For the purposes of ISEM, these conditions could advantageously be formulated into a goal programming type model. In this type of model, only the resource and mobility limitations are absolute. Such things as conflicting policies and goals are sequentially relaxed in such a way that (a) a feasible solution will exist if the resources exist, and (b) the feasible solution minimizes the weighted discrepancies between goals and performance. The "weighting" of goals (or policy objectives) would reflect the relative priorities of the policy objectives that constrain potential allocations. The goal programming algorithm would be constructed to allow the time phased introduction of new forces as they become available through mobilization of the reserves and as they exit training pipelines. It could be set up to generate the potential buildup path and to detect the classes of skills in which bottlenecks begin to form. By relieving these bottlenecks as they appear, using dummy sources, the whole resource base could be assessed with respect to each scenario. Numerical indices could be devised to indicate the force readiness state with respect to each type of scenario. For example, a given personnel force composition can be translated into a specific sortie rate launched from a specific location using existing manpower standards. If this is the relevant measure of effectiveness, one could construct a trajectory that would reflect the effective capability of the personnel system to support the contingency.

III. PROPOSED CONTENT FOR THE INTEGRATED SIMULATION EVALUATION MODEL OF THE AIR FORCE MANPOWER AND PERSONNEL SYSTEM

Overview

The ISEM concept involves the development of a descriptive model that links four subsystems:

1. The Policy-Information-Control System (PIC).

2. The Personnel Force Structure (FS).

3. The Training and Transportation Pipelines (TTP).

4. The National Labor Markets (NLM).

These elements will be tied into a fifth key part of ISEM: The systems Evaluation package.

The PIC, which is a bureaucratically organized administrative control system, has a set of transfer functions which convert (a) its perceptions of current and future force structure states, and (b) general policy and program directives, into very detailed instructions for adjustment and augmentation of the internal resource pools. Its dynamic response to change is a function of the structure and of its information flows and its operating policies. Its outputs take the form of verbal reports and instructions.

The FS is a complex of internal resource pools which delivers the skilled labor services required by the Air Force and have their own internal dynamics in the sense that they are involved in a "pure death" process. They are always being depleted over time by attrition and skill perishability. Internally generated attrition is derived from a continuation decision for members making occupational choices, by death, and by the institutional career lengths imposed in the internal labor market structure. Skills are maintained when they are used, but perish when they are not used. Since the Air Force allows cross-training and career broadening, and maintains a rated supplement, skills are always being lost from lack of use even in the active duty force. When the reserve forces are considered, the effect becomes even more pronounced. This is significant since a relatively high proportion of Air Force Reserve and Air National Guard forces are classified as "tooth" rather than "tail" elements.

The T&TP is a mechanism which modifies people to prepare them to be moved from one job to another (training) and then actually transports them. Its main behavioral variable is the time required to move people from one job to another. If there are strict competence standards at the receiving end, the chief parameters which affect the movement time are the characteristics of the personnel aggregates (as opposed to individual people) flowing through the system. Thus, for any class of trainees going through, say, a basic electronics course, flow time through the training course depends upon the expected minimum aptitude of all people in the group (i.e., how course length is set—so that the lowest aptitude person in the class can be trained to standard). Further, the flow rate will depend upon the source of the flow. Moving a technician from a reserve unit to an active unit may involve a differently structured and presumably longer channel than movement within the active force.

Flow into and out of the Air Force organization involves the confluence and interaction of Air Force policies and the state of the national economy. The Air Force essentially proposes an employment contract (including a compensation package and an employment term) and a set of working conditions which people within and outside of the organization can take or leave at appropriate times. Further, it restricts the offer to a limited group of people within the total labor market at the port of entry with rather strict age and aptitude qualifications and at points of exit with performance requirements. The inflow and outflow under these conditions appear to be a random walk depending upon the size of the pool of qualified availables and their available alternative employment opportunities. If it can be assumed that working conditions within the Air Force are largely technologically determined (and therefore are invariant for relatively long periods of time), then the chief policy tools the Air Force has available to maintain an objective force level are terms of employment and entrance qualifications. A secondary and more uncertain policy pool involves increasing the size of the pool of availables by reshaping the Air Force public image. The response of the labor market (internal and external) to any particular set of tools will depend on the states of a large number of submarkets; i.e., the markets for particular types of skilled labor services. The states of all of the skills markets are constantly changing—this leads to differentials in retention potential across Air Force skill classifications.

The final element in ISEM is the Systems Evaluation package which will selectively monitor and evaluate the dynamic behavior of the descriptive model of the AFMPS. The evaluation package will be conceptually and factually distinct from the descriptive model of the AFMPS. The output of the evaluation package will be a comprehensible set of indicators of the status and performance of the descriptive model. One problem that must be faced in the evaluation package is that certain policies introduced to correct short run situations in the AFMPS may lead to severe degradation of the system within the period of simulation. If the model is to be truly descriptive of the system at any point in time, it must incorporate those policies in its structure. Yet these policies will, in the real-world case, not be pursued to system extinction. As the impacted groups of state variables deteriorate, feedback is received from operational

sources to force policy change. In ISEM, such an external override must also function. This will be done by establishing management control thresholds on key variables. When the thresholds are violated by state levels, the simulation will be stopped and terminal conditions stored. The program could be restarted after diagnosis and fix. After this point of termination, of course, the model will no longer be descriptive of the existing system and probably not of the future system unless the model is actively used in policy formulation.

Each segment of the model, of course, has a definite corresponding component within the AFMPS or the national economy. Figure 1 gives a layout of the program as it is currently envisioned. The PIC module will correspond to the administrative control system of the AFMPS. It will represent the policy structure defined by the Assistant Secretary of the Air Force for Manpower and Reserve Affairs (M&RA), the Deputy Chief of Staff for Programs and Resources (PR), and the Deputy Chief of Staff for Personnel (DP) functions. In the case of PR, the policy functions relevant to ISEM are carried through by the Director of Manpower and Organization (PRM). Daily operations of the military personnel subsystem are carried through by a triad structure of the Air Force Military Personnel Center (AFMPC), major command (MAJCOM) personnel staffs, and local consolidated base personnel offices (CBPO). Within this structure there is a strong tendency

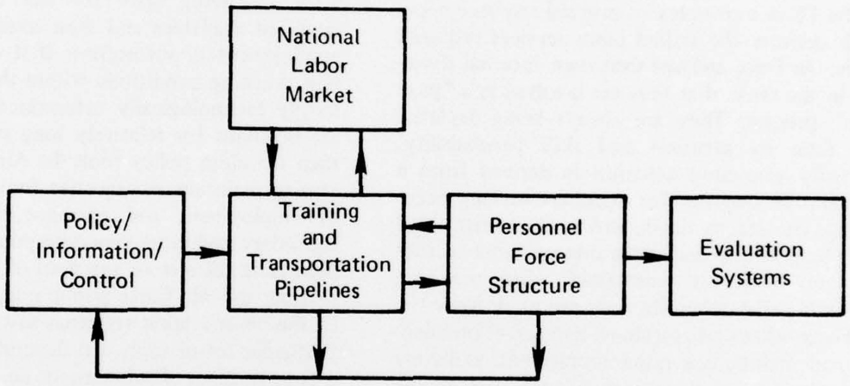

Figure 1. **Basic elements of ISEM.**

toward centralized decision making and control, although the trend has slowed as MAJCOM Commanders have become more and more resistant to losing control of their vital personnel resources. The manpower function is operated through the MAJCOM, management engineering team (MET), Air Force Management Engineering Agency (AFMEA) triad. The MAJCOM manpower function is still the key to the operation of the manpower system. Indeed, the local level METs are detachments from the MAJCOM headquarters and not commanded by anyone on a base (excepting the MAJCOM headquarters base). The AFMEA is a relatively new agency established to develop functional manpower standards that cut across the MAJCOMs. Its development is facilitated by the Command Manpower Data System (CMDS) that standardizes and centralizes the data processing capabilities of the manpower subsystem.

The Training and Transportation Pipelines (T&TP) module of ISEM will represent three disparate elements of the Air Force. One is the Air Training Command (ATC). The Air Training Command is a major command within the Air Force charged (roughly) with providing a major portion of the basic and technical training for Air Force personnel. It will be represented in the T&TP in terms of training times, success rates, and course capacity. The Air University is a MAJCOM charged with providing professional education to Air Force personnel. It will be represented in the same way as ATC. Both functions will react to PIC requirements to increase, decrease, start or stop a training or educational course. Both will also be represented in terms of their force structure components in PIC models and the force structure module. The third element of the T&TP is the transportation system. Because of the enormous transportation capacity for moves within and

outside the continental United States (CONUS), there are no peacetime capacity restrictions on any conceivable rates of movements in the AFMPS. The only really relevant problem is the computation of movement times. While there are standard allotments of time allowed for moves (related to the distance of the move, at 350 miles per day), people can also take leave en route at their option (up to 30 days) under normal conditions. This seems to be easily and clearly representable, however, by developing an empirical sampling distribution and using Monte Carlo techniques.

The personnel force structure will correspond to the people in the Air Force in all force components (civilian, active duty officers and enlisted, selected reserves, and Air National Guard).

The national labor market module of ISEM will be developed in terms of two submodels—one will develop the decision structure of the internal/external labor market interface. This submodel will establish the type of information that is used in the accession-continuation decision, how it is used, and when it is used. The second submodel will predict an expected sequence of information signals that will enter into the accession-continuation decision.

The Systems Evaluation will hold the various algorithms, accounting structures, and standards by which the AFMPS behavior will be monitored and evaluated. This module will be continuously developed as experience with the descriptive model is accumulated. Some aspects of the module will be based upon highly experimental concepts—this module will not directly influence any part of the descriptive model's functioning unless the AFMPS actually adopts some of the force management concepts invented for the module.

The full-scale ISEM will be developed as an integrated composite of five modules. The modules will be developed and tested so that they can have independently useful peel-offs. Detailed descriptions of the envisioned modules of the system are presented below.

The Policy-Information-Control System (PIC) Module

When viewed in isolation, the manifold function of the PIC can be comprehensively stated only at a fairly high level of abstraction. The PIC is the administrative system that precipitates all goal seeking activities in the AFMPS. It is comprised of: various functional hierarchies that act as decision making chains for the system; a formal cognitive structure which organizes all of its information into perceptions of the state of the system; and a network of data transmission, processing, and storage facilities. Each functional hierarchy has prioritized goal and policy sets which, at the lower level of the hierarchy, at least, are in conformance with the various classification systems of the system cognitive structure. In general, the following processes characterize both (a) the routine activities of the parallel functional hierarchies, and (b) the gross routine activity of the PIC. The PIC:

1. Collects categorized data that are transformed into perceived system states as mandated by the classification systems of the cognitive structure.

2. Compares perceived states with the ideal states expressed by the goal structures and identifies discrepancies.

3. Searches a policy-restricted set of potential remedial actions and selects an action sequence that the decision element infers will cause future system status reports to change so as to diminish the detected discrepancies with the goals.

4. Performs all information storage, transformation, and transfer necessary to support the above functions.

A "complete" model of the PIC is impossible to formulate. This is not so much due to its extreme complexity as to the fact that it contains effector components with the capacity for novel behavior. This sort of behavior cannot be predicted or proxied by random elements in any useful sense. To be successful in this effort then, the inherent limitations of modeling must be acknowledged. The model will instead focus on the persistent system structures and routines which limit and resist novelty, such as information flow patterns and time requirements for information use in decision. All novel behavior will be introduced into simulations as exogenous inputs. Based on the preceding, ISEM will represent and interpret the following interrelated PIC functions:

1. Conversion of overall budget plans into expenditure category constraints and adjustment of constraints as required for viable system operation.

2. Conversion of year-end strength limitations into personnel strength goals by force components, skill, skill level, and grade.

3. Assessment of mission mandated manpower requirements; allocation of Air Force manpower authorizations to mission elements; adjustment of allocations to meet technology changes.

4. Classification of force structure elements by aptitude, skill and education, grade, location, function, organization and force component.

5. Development of requirements for procurement, training and education, promotion, assignment, separation and retirement.

6. Recognize demands for assignments, separations and retirements.

7. Decretal actions to: authorize recruitment; assign, promote, separate and retire personnel; *schedule training and education assigments and* flows; and incentivize retention or voluntary losses.

The construction of the PIC module will require the collection, organization, and analysis of a very large amount of data about the structure of the information system and decision logic of the AFMPS. This process will be greatly facilitated by the availability of a very powerful computer program developed by the Navy for such applications. Technique for Interactive Systems Analysis (TISA) (Barefoot & Blanco, 1976) combines a set of network analysis and display programs with a data base management system to assist in the process of abstracting out and aggregating the important features of the PIC. The programs operate on data gathered using special survey instruments designed and tested for use with the programs. (Research indicates that much can be learned prior to the execution of surveys and use of TISA, simply through a perusal of the regulations and documentation, which guide the use of the various elements of the personnel/manpower management system. Indeed, work on a prototype model has captured a very significant part of the decision structure without going through formal surveys.)

One other aspect of the PIC is that the way it is configured has important implications about the resource consumption required to manage the AFMPS. Different levels of activities will be associated with different manpower requirements to operate at those levels, and will be directly reflected within the PIC through the manpower system requirements process. It will be further reflected within the FS and the evaluation module in terms of personnel and cost flows.

The Personnel Force Structure (FS) Module

The FS Module will be a representation of the human resource pools available to the Air Force aggregated into the major management categories recognized by the PIC. In essence, the FS personnel aggregate will be established by an intersection of location (base of assignment), unit of administrative control (Major Air Command or force component ownership), skill (including skill level), years of incumbency in a job, function (type of mission element), time in the Air Force, and grade (whether civilian, officer, or enlisted). In a fairly detailed disaggregation, there could be included: 250 bases, 25 MAJCOMs, 2,000 skills, 10 years of incumbency groups, 1,000 functions, 30 year groups, and 10 grade levels, which yield upwards to 3.75×10^{13} (37.5 trillions) possible categorizations. Inasmuch as the entire personnel force has only about 1 million people, there can only be about one person per 37.5 million potential categories. In other words, the vast, vast majority of potential categories would be empty.

It follows that it would be very inefficient to represent the force structure as a matrix. Rather, it would seem reasonable to "hierarchically order" the seven dimensions into, say, MAJCOM-base-function-skill-grade-incumbency-year groups, and let each level represent a stage in a network. By storing the force as an accumulation at nodes of a network, much unnecessary computer storage can be saved. For instance, as one tracks down the network, he may find that a MAJCOM does not have any people assigned at a particular base. This single finding will allow the elimination of all storage locations for that MAJCOM at any level after that base (6×10^9 categories). This representation is conceptually similar to the idea in SIMSCRIPT II.5 of the use of pointer variables for dynamic storage allocation for sparse arrays.

For many practical purposes, however, even if it is feasible to store the force structure at the level of disaggregation indicated, it would not be terribly useful to do so. In particular, with so many categorizations, the model is almost describing the force structure at the entity level. This greatly complicates the decision logic of the model. Therefore, certain elements would appear to be better described in terms of larger aggregates. For instance, the importance of year group is its strong correlation with grade and attrition rate. Thus it would seem useful to establish more aggregate categories (such as year 1, years 2–3, year 4, years 5–8, years 9–19, year 20, years 21–25 and years 26–30) to match attrition patterns. Years of incumbency on the job are important due to differentials in assignment vulnerability, particularly in overseas jobs with mandatory rotation after a *fixed tour length*. Appropriate incumbency categories might be less than two years, three to four years, and greater than four years. Grade levels too could be compacted significantly for most applications–for instance, it might be

feasible to represent officer grades as 0-1 to 0-2, 0-3, 0-4 to 0-5, 0-6, 0-7 to 0-10. Enlisted grades might be compressed in E-1 to E-3, E-4 to E-6, E-7 to E-9. A practical breakdown of GS-type grades could be GS-1 to GS-2, GS-3 to GS-6, GS-7 to GS-11, GS-12 to GS-15, GS-16 to GS-18. These aggregations would reduce the force structure model by a factor of about 10,000 and would greatly simplify the adjustment of the force in response to PIC decrees.

Current Air Force data files permit the force structure to be modeled using existing data. This brings out the point that the PIC already has three structurally parallel models of the personnel force within its cognitive system. These models are essentially the fully disaggregated model outlined previously. The only difference is that in the model of the force used by the personnel system, the number in each category is the number of people reported to actually fit the category. The other two models, maintained by the manpower system, contain the number of people *authorized* by the budget as scaled across the force and detail the requirements based upon the technological demands of the mission.

The FS module will represent none of these. It will be the actual state of the simulated FS, as opposed to the FS as perceived by the PIC through errors in reporting, allocation, authorization and requirement. Such errors might appear in particular data collection and processing procedures to make the numbers in the PIC cognitive structure differ considerably from those in the FS module.

Training and Transportation Pipelines (T&TP) Module

The T&TP is a separate module in ISEM because the PIC, and especially the personnel subsystem of the PIC, only in certain cases directly effects changes in the FS. This is true in the sense that orders do not actually move people–aircraft and trains and automobiles do–and the establishment of training requirements and posting of records do not vest skills in people–instructors and instructional aids and study and practice over time do that. The T&TP module will be a fairly complicated structure. It will assume what is basically a transducer function that connects the PIC to the FS module: it will form the pipeline through which personnel flows occur. In particular, the following functions will be featured in the T&TP module.

1. Receipt of assignment decrees from the PIC: routing of personnel through required training and transportation as instructed; signal to FS module to debit the proper number of people in each categorization or pipeline at the appropriate time; signal to FS module to materialize proper number of people in each category at proper places in training and after requisite travel and training have occurred.

2. Receipt from PIC of recruitment quantity and inducements authorizations and conversion to maximum inflow limits; receipt of inflow potential from the National Labor Market (NLM) module; effecting categorical inflow of people into the Air Force based on inflow potential from NLM, inflow authorized, and authorized wages and incentives.

3. Receipt and conversion of loss management instructions into FS-compatible classifications. Debit or extend numbers of people in the proper categorizations where positive actions are possible and feasible.

The T&TP module will not only involve "pipelines." Also, flow rates through the various channels will influence manpower requirements needed to service the channels. This fact will be detected by the manpower subsystem of the PIC, be transmitted to the assignment system, and then fed back to cause flows through the T&TP after time lags.

National Labor Market Module

This module will determine the ultimate resource constraints the Air Force faces in the volunteer environment under specified compensation systems offered by the Air Force. The model will predict the inflow potential of new recruits and the demand for separation by people within the system based upon two basic submodels:

1. The Internal-External Labor Market Interface: A decision model that properly arranges the economic variables as they enter the accession/continuation decision.

2. The National Skills Market: A predictive econometric model of (a) the skills markets within which the Air Force is a competitor, and (b) the demographic composition of the population.

Each of these submodels represents significant research efforts and would be independently useful to Air Force management decisions. The outlines of the two models are presented as follows.

The Internal-External Labor Market Interface. The concepts for the interface model are largely derived from the work of Drs. A. S. DeVany and

T. R. Saving of Texas A&M University under Air Force contract. This subsection largely excerpts their (DeVany, Reynolds, & Shughart, 1977) preliminary draft report. Many questions key to the construction of a theoretical model of the internal-external labor market interface have been under consideration for some time. There has been considerable research on the relationship between military pay, recruiting effort, general business conditions and the accession and retention rates of the various military services. The results of past research have improved the understanding of the economic factors which influence the attractiveness of the military as a career choice. In particular, considerable work has been directed toward understanding the impact of various bonus options for enlisted personnel and officer continuation pay on retention at selected career decision points. What is missing is a general economic model designed to explain the effects of voluntary accession and attrition on the distribution of military manpower over age and skill cohorts. Specifically, the existing models fail to account for the uncertainty on both the demand and supply sides of the market.

Essentially, the uncertainty implies that for given wages and minimum acceptable AFQT scores there will at times be periods where demand for personnel exceeds supply and other periods when supply exceeds demand. Those periods where supply exceeds demand will result in queues of volunteers who must wait for accession. The length of such queues will affect both the number and quality of applicants. The same process applies to promotion and consequently the movement of a recruit through his career can be characterized by a serial queue. At each decision point in the career process, both the Air Force and the individual can exercise options on the individual's decision to remain in the system. The Air Force can "fire" or "lay off" an individual by declaring him not eligible to reenlist; those eligible to reenlist can "quit" by not executing a reenlistment contract. The length of the various queues will affect these decisions and accordingly affect the distribution of quality for any given level of Air Force manpower. Of particular interest to the Air Force is not only the percentage of end strength attained for a given fiscal year, but also the distribution of personnel by pay grade and length of service. Further importance is attached to the career structure within military occupations—Air Force speciality codes (AFSC).

Failure to recognize the importance of the queue of applicants is not an omission of manpower studies alone, since the general competitive model has not been developed to reveal the joint determination of price, quality and quantity. What is required is the extension of existing models of occupational choice by introducing uncertainty and search in a way that sheds light on the determination of manpower quality and quantity.

On the supply side, assume that at each decision point in an airman's or officer's career, he evaluates alternative civilian careers in present value terms. In particular, such an evaluation is made prior to initial enlistment. Individuals in the resource pool (commonly known as Qualified Military Available) do not have complete information concerning the alternatives available to them. Accordingly, they search over possible employers and since these prospective employers will not value any given searcher equally, different employers will make different offers to a given searcher. Given the costs of search, the searcher will select a reservation wage for each occupation.

The reservation wages are determined by the individual searchers' assessment of the various occupations and the costs of search. Initially, the decision makers have little information concerning the alternatives so that the reservation wages are likely to be similar. Initial career decisions are made on the basis of the first job offer which exceeds the reservation wage.

Once an individual makes the initial career decision to join the Air Force, the Air Force makes a training investment to develop his skills. Once this is done, it may become profitable for him to resume search. The institutionally appropriate time for occupational reevaluation by Air Force personnel is at the end of the first enlistment period. The likelihood of renewed search is a function of the form of training investment during the initial enlistment. In particular, the more employer-specific the investment, the greater the reservation wage when searching across employers in the same career area. The more career-specific the investment, the greater the reservation wage for other careers.

This observation is supported by evidence that first-term reenlistment rates are not uniform across military occupations. In general, individuals whose initial training raises their marginal productivity to civilian employers reenlist at lower rates than do individuals trained in military-oriented occupations. Thus, the services experience periodic "shortage" of personnel in some job classifications and "overage" in others. Selective use of

reenlistment bonuses has been applied in the former case, and the introduction of incentives for lateral conversion of occupation in the latter. These types of policy tools represent changes in queue discipline and highlight the endogeneity which the model must consider.

If demand exceeds supply for manpower in general or for specific occupations, then bonuses, faster promotion cycles, and selection of all personnel above some minimum acceptable quality level are likely to be undertaken as corrective measures. On the other hand, if supply exceeds demand, bonus levels may be reduced or eliminated, promotions delayed, and selection priority given only to the most highly qualified individuals. The policy changes in turn affect individual searchers, altering balking probabilities and introducing other behavior such as "reneging" (leaving a queue after having already entered the system) and "jockeying" (switching queues either within or between the civilian and military sectors).

Just as prospective employees search for job offers, employers are searching for employees to fill vacancies. At any given wage rate offered there will be a distribution of prospective employees of marginal product, or quality, who would accept employment at that wage. Since the marginal product or quality of any given individual is not known with certainty, the employer has an *incentive to invest resources in* order to estimate this quality. This uncertainty leads, for example, to employers testing of prospective employees.

For any fixed wage, vacancy rate and costs of search the employer will select a reservation quality. The reservation quality will depend on the wage offered, the rate at which vacancies must be filled and alternative wages. Thus, given the arrival distribution of searchers, the distribution of vacancies, the offer wage, the reservation wages of searchers and the reservation quality of employers, the expected quantity of recruits is determined.

If this expected quantity will not maintain the desired steady state force strength or strength trajectory, then some change in wages or reservation quality must be made. Even if the expected quality is exactly sufficient to maintain the desired steady state force strength, the actual level of strength will be a random walk. If the desired and maximum strengths are equal, then during those intervals in which supply exceeds vacancies a queue will develop. On the other hand, during those periods when demand exceeds supply, the reservation quality must be lowered if strength is to be maintained. The queue on the supply side results in potential employees waiting for jobs and such waits will affect the arrival distribution; a phenomenon known as "balking" in the queueing literature. Thus, the existence of queues will affect the level of search and ultimately the equilibrium arrival rate of searchers.

From the previous discussion, it is apparent that the level of wages, the reservation quality of recruits and the desired manpower strength are not independent. That is, only two of these variables can be independently chosen. In addition, even if these variables are at levels consistent with a steady state of equilibrium volunteer force, if a fixed quality is to be maintained then quantity must be a random walk.

The interface model will be developed as outlined previously. It will attempt to explain the fact that markets become segmented because prospective employees and employers do not search over their entire respective available pools. In fact they limit their search more and more as they develop better information concerning labor markets.

The model will treat the number of individuals in each skill-age cohort as determined by a stochastic process and apply the general theory of queues to the problem of Air Force manpower procurement and retention. This approach treats the initial enlistment point and subsequent reenlistment points as steps in a serial queue. At each queueing point some proportion of the members balk. These balks are functions of relative wages, unemployment rates, promotion policy, and manpower quality requirements. The model will specify when and how information about these factors enters the basic accession and continuation decision for Air Force personnel. The information used evolves in the various skills markets within which Air Force personnel compete. This then leads to the second part of the National Labor Market module.

The National Skills Markets Submodel. The problem of constructing a submodel to project conditions for the skills market within which the Air Force is a competitor is indeed formidable. The reason that such a model is desirable for ISEM is the fact that much of the dynamic behavior of the personnel system is driven by attrition rates for skilled people. The assignment system must constantly work to fill vacancies left by attrition from resources existing in the force and from people flowing from training pipelines. Since the pipelines have significant lead times, attrition must be projected up to several years in advance. Since

the market values of skills acquired in the Air Force vary widely, attrition will vary across skills. Further, as external industry demand changes and technology develops, the relative market values change among skills. Thus, there is no assurance that past attrition rates say anything about future rates, especially when attempting to discriminate to the level of attrition in individual skills. The Air Force has long recognized that its inability to predict peacetime continuation rates presents a definite planning problem.

There are two basic approaches under consideration for developing the model of the skills markets. One approach is the "traditional" econometric approach which uses the general linear model to organize an ensemble of market data into a set of simultaneous equations. The problems of estimation and testing of these types of models are well known, especially in the case of large simultaneous equations system models which would be required to include most of the information available about the skills markets. (In fact, these authors know of no successful scientific application of simultaneous equations system techniques for predictive testing that involves more than four equations.) The econometric approach, however, must be attempted and tested before it can be discarded. It is the approach that has been developed over a long period of time to represent large simultaneously determined systems and conforms to known testing and validation procedures.

The second approach is philosophically much more closely related to the methods of the AFMPS representation. This is the "Systems Dynamic" approach introduced by Jay W. Forrester at Massachusetts Institute of Technology (MIT). This approach is being intensively developed for application to the representation of the national economy by the Systems Dynamics Group at the MIT Sloan School of Management. It uses a feedback control system representation at a relatively high level of aggregation to establish a dynamic simulation model of the national economy. This approach has good potential for developing the broad outlines of the evolution of the American economy. The problem with the systems dynamics approach to date is level of aggregation. The goal of ISEM is to be able to predict attrition to the level of individual skills, and systems dynamics attempts to avoid this level of detail.

No matter what the technique used in the final analyses, the submodel which represents the national skills markets is conceived of as follows: consider the national economy as being segmented into industrial categories, where each industry uses relatively fixed proportions of skilled labor service inputs. As each industry grows or contracts, its demand for various types of labor services increases or decreases over the short run (unless a major technological transformation occurs during the cycle). Each industry then represents a specific component of the total market demand for each type of labor services. There would be many components of market supply. With upward wage pressures in the skills affected by growth, educational resources would be increasingly allocated to the growth area. A significant proportion of the people going into the growing industry would be new entrants from the educational industry, since they would have lower occupational attachment (and marginal mobility costs) to previous jobs. In static or declining industries, the work force would tend to age. Such industries could even become net sources of supply for skilled labor services through the mediation of an unemployment pool for each skill. In fact, in those industries where skills have a large amount of job specificity, retreating industries would supply workers to the market for "unskilled" workers.

The Air Force enters these markets as (a) a competitor, and (b) a member of the educational industry. The Air Force recruits new enlisted and officer personnel from the ranks of people mostly with no more than basic general skills. For the officers, of course, these general skills may be somewhat more intensively cultivated, because of college degree requirements and because the officer candidates are older than new enlistees. In the course of their tours, people receive training in various skills, some of which are more transferable than others. At the end of initial commitments, the Air Force competes in the markets to retain their services.

This leads to two basic effects relative to the labor market. Since the Air Force often guarantees training in particular skills before initial enlistment, if it offers training in skills for which total industry demand is growing relative to supply, it will have an increased inflow of applicants in that skill. Second, unless it adjusts its pay scales, it will have great difficulty retaining first-term enlistees after the first enlistment expires.

What the Skills Markets submodel would attempt to do would be to predict the price vector across all skills markets for a five-year period. It

would do this by predicting (a) relative growth rates among industry categories, (b) demographic shifts, (c) supplies of new entrants into each skill market, and (d) inter-industry shifts of skills. The demographic shifts would be the easiest to predict for such a short run period as five years. In fact, such variation would be mostly exogenously determined. The supplies of new entrants into each skill market would be easy to predict for some components where the training lead time is long and more difficult and endogenous where lead time is short. Relative growth rates and inter-industry shifts of skills will, of course, be closely related and most difficult to predict. One would expect that the projections will be made on the basis of hypotheses about recent levels of capital investment in each (and complementary) industry and about the progression of inventory cycles. Such projections will be further conditioned by the overall growth in aggregate demand for the economy as long term economic cycles evolve. It would probably be outside the scope of ISEM to attempt to endogenously determine these overall growth and business cycle factors. Rather, various economic forecasts could be played against the ISEM submodel to develop the overall impact of the economy on the AFMPS. These forecasts could come from the various economy-wide simultaneous equations systems models available commercially or the new systems dynamics models being developed.

The Systems Evaluation Module

The ISEM evaluation module will initially consist of several techniques for controlling data input, for displaying trajectories of state variables, for displaying internal configurations of the model, and for transforming the outputs of the descriptive model. With respect to the controlling exogenous inputs, ISEM will have a set of controls that will:

1. Allow the arbitrary specification and automatic introduction of a sequence of changes to internal decision functions at any time during a simulation run.

2. Allow identification and automatic monitoring of the values of arbitrary variables. Also, for the identified variables, the module will allow the specification of threshold values. If, during the simulation run, the threshold is crossed, the module will automatically interrupt the simulation, identify the causative variable and store the internal configuration of the program. After this, the user may introduce a new policy or decision and restart the simulation from the point of interruption. The controls will be constructed so as to allow a time phased introduction of the new policy after restart.

3. The exogenous input sequence controls will input values for appropriate exogenous variables into the ISEM as required to simulate interface with the external environment.

The evaluation module will have default standard displays to handle specification of outputs of ISEM, or

4. Permit the user to specify any explicit variable to be monitored. Value plots (trajectories) of the specified variables will be stored for output display.

5. Permit the user to call subroutines from the evaluation module to transform the stored variables' trajectories. The output of these subroutines will be stored for output display.

6. Permit the user to specify PIC decision action sequences to be monitored. The module will store for display the information-coordination-decision action flow among nodes in the PIC.

7. Permit the user to select available display options for reporting each variable type monitored.

Further, the data output will be displayed in many different modes. The following outputs will be included in the initial version of the system:

Tabulated Trajectory Display. This routine will print in numerical table form the data specified for monitoring by the user.

Dynamic Plot Display. This display mode will plot on a scaled graph a selected subset of the data points specified for monitoring.

Internal Configuration Display. This output mode will graphically display specified link-node segments of the internal decision logic network in the PIC.

Decision Sequence Display. This routine will develop a graphical information flow sequence diagram to display the PIC sequences specified by the user.

These data outputs can be then transformed to suit the format for one of the standard statistical analysis packages if required for particular experiments.

Three important features of the evaluation module are the cost accounting system, the human

resource accounts, and the force response algorithms. The cost accounting system will monitor various activities within the administrative system, the personnel force structure and the training and transportation pipelines and use a set of standard relations to transform these activities into cost accounts. This structure will be developed to compute rates of flow as well as cumulative costs.

The evaluation module will also have two human resource accounts. First, the skill delivery rate, an aggregate account, will be developed to show the maximum rate at which the Air Force can deliver any particular type of skilled labor service if it allocates to all people with a particular skill or a closely transferable skill the performance of a particular task. This type of aggregate will be increased whenever the Air Force trains a person into a given skill category. If the person cross-trains and takes another job, he will leave that skill category in the force structure model, but not in the human resources accounts. In this accounting he will be carried in both accounts until his human capital depreciates from lack of use or until he leaves the service. From these skills delivery rate accounts (measured in units of "men") will be derived a second account—a total human capital service fund for each skill.

The human capital service fund will be the expected number of man-years by type of skilled labor service that the Air Force can potentially obtain from the people it actually has in the force. This measure would be developed based upon the following hypothetical concept: suppose we have a given number of people in the force with the certified ability to perform a particular type of service. Based upon labor market factors, their time in service, their job performance, Air Force policy and normal mortality factors, these people will separate from the service at some rate until all are gone at the end of H years. If one can estimate the attrition rate for the force at each time point in the future, the convolution integral of the trajectory of rates will be the total number of people in the force at each point in the future. The integral of the function so developed is the total number of man-years that can be delivered over the future (if no new people are brought into the force) by the force in being. This number would represent the work capacity of the force at a given instant.

These two human resource measures (skills delivery rate account and human capital service fund) can be manipulated and interpreted to indicate several things about the macrostate of the personnel force. For instance, the ratio of the sum of the skills delivery rates for the entire force to the number of people in the force might be construed as a measure of force flexibility—this could be tracked to determine the progress of skills development in the force. The ratio of the skills delivery rate to the human capital service fund capacity could be a measure of force age for a skill. As the number increased, "age" would increase and there would be an indication that an increasing portion of the force would have to be replaced in the near future.

Another important feature of the evaluation module will be the force response algorithms. These will be a group of system features that take the personnel force arrays and set them up as resource constaints in the goal programming algorithm discussed in Section II. Further, the algorithms will coordinate the introduction and modification of contingency scenarios and set up the structure of a function-location array that will be used to satisfy mission task requirements. The algorithm will fill the function-location array based upon congingency force structure packages; this function-location array will be compared to the contingency scenario network on the basis of how many manhours the array can deliver against skilled task loadings required by a designated mission. Of course the ability of the array to deliver skilled labor services will depend upon both the number of people with the skill and the length of the workweek. The model would make the comparison based upon some theoretically maximum sustainable workweek to detect undermanning and upon a policy determined minimum to detect overmanning.

IV. ISEM UTILIZATION

If the Air Force is to commit resources to the construction of ISEM as a tool for policy analysis, it is important that there be some institutional method of capturing its potential benefits. For many reasons, some of which are outlined in the sequel, the current Air Force planning structure is not ideally suited for the policy analysis function. Rather, some organizational adjustment is needed to cope with new policy analysis concepts. Actually, there is nothing new about this requirement.

According to former Secretary of Defense, James R. Schlesinger, the Department of Defense has been making long run organizational adjustments since 1961 to achieve two broad objectives.

To wit: "One objective was to achieve better co-ordination of interrelated decisions than that which 'bargaining' among the services could provide. The other. . .was to improve choices in general: (a) by looking at full costs rather than down payment implications of alternative policies, (b) by costing in terms of programs or 'outputs' rather than inputs, and (c) by systematically considering alternatives and tradeoffs in terms of cost-effectiveness." While the need to achieve these objectives within the Air Force is well understood and supported in the Air Force, the means of fulfilling them (particularly for the latter objective) is not readily available in many areas. This is especially the case when there exists a basic conflict in the planning requirements. For instance, the c-part of the second stated objective implies an exhaustive determination of the outcomes of possible decisions under all feasible policies. This sort of process is difficult, exceedingly time-consuming, and clearly cannot be carried through while responding to planning requirements for operational contingencies.

With the possible exception of its R&D community, the Air Force organizes and drives its planning staffs primarily to assure that viable solutions are available to operational questions. For major mission contingencies, this is done by preestablishing a deep functional planning hierarchy that coexists with and responds to the needs of operational elements. The structure is set up to allow each staff element to execute a policy-restricted search of decision options to satisfy its contribution to a total plan. The results of this search are then passed up the hierarchy to co-ordinating and consolidating staff agencies which perform the same sort of function at a higher organizational level.

The advantages of this process are several: (a) parallel processing at each level of hierarchy allows very rapid performance of even massive efforts; (b) the information available to the hierarchy is as complete and realistic as it can be, since it is generated at the unit level when the planning sequence is executed; (c) it works; i.e., it produces a viable solution if there is one within the policy and resource constraints. The limitations of the approach are clear, however. For instance, as the process typically operates, the policy restrictions are "unidimensional." While this is necessary for rapid response and close coordination, it is a severe limitation on the number of options considered. This may be serious if the contingency that is being met is not rather fully anticipated in the policy set promulgated for the planning exercise. Further, because of the limited functional and organizational horizons of each staff, potential tradeoffs cannot be recognized–and the information required to make tradeoffs is often filtered out before it is passed up.

In an organization as large and complex as the Air Force, there is no practical way to enforce uniform standards of performance among the subanalyses. Thus, there is no way to assess the total distortion of information that flows up the hierarchy (the implication of this bears directly on the executability of the plan produced). Finally, of course, priorities typically assigned to the activities of the scarce planning resource embodied in the hierarchy place the immediate Air Force mission contingency first, local mission contingencies second, with long range policy analysis relegated to the slack of which there is none. The bottom line of all of this is that Air Force planning staffs are not especially suited to policy analysis.

Essentially, policy analysis should be an ongoing process of internal constructive criticism. Its function is to ensure that the Air Force does not unnecessarily restrict its decision options by allowing man-made decision rules to assume the inviolable character of physical constraints. As Dr. Schlesinger points out: "In principle, some institutional means for fostering constructive criticism can be created. In practice, however, the problem would be to prevent such internal institutions, obstensibly devoted to study of the long run, from being turned like everything else to the pursuit of short run objectives."

One solution to the problem of policy analysis is to establish ad hoc working groups such as the Defense Manpower Commission or the Air Force Management Improvement Group. Several situations limit the usefulness of this approach, however. For one, such groups are temporary. They do not operate over a long enough period of time to invest resources in developing efficient analytical methods, so their work is performed in a very labor intensive manner. In general, their time horizon makes them concentrate on immediate problems–further, they do not expect to be accountable for the implementation or results of their suggestions. This often tends to make the breadth and eloquence of proposals exceed the depths of supporting analysis. Too, it is expensive to establish and disestablish such groups. The life cycle of such a group involves pulling highly skilled people from regular jobs, organizing them, building up their individual and corporate knowledge about the area of endeavor, extracting some

initial impressions from them, and then sending them back to their old jobs. This, of course, costs the lost production in their regular jobs, and dissolution of the group represents a low return divestiture of human capital. Of course, once the group has dissolved, there is no one to defend its proposals against attack, so, unfortunately (or otherwise), follow-through on proposals is at best uneven and uncertain.

Another approach to the problem of long range policy analysis, and the one advocated here for ISEM implementation, is to develop relatively small groups of highly skilled individuals who can devote full time to the work over a long period. The keys to the effectiveness of such groups include:

1. That the subject of analysis be functionally oriented. This is because policy that applies Air Force-wide is established functionally.

2. That the area of analysis be broad enough to fully describe a controlled input to the primary Air Force mission process. If this is not the case, then there is no basis to establish meaningful external measures of value to functional operations controlled by the policies under consideration and, thus, no extrinsic basis for evaluating benefits of changes.

3. That the technology used by the group be highly capital intensive. This is important so that a relatively small group can deliver policy analyses in a rapid response mode; this allows the full capture of the benefits of the low cost information exchange that is only possible in small groups.

4. That the policy analysis group be separated from operational lines by allowing direct reporting to the lowest level of full functional responsibility. This is required to keep the efforts of the group directed at policy analysis rather than decision analysis while focusing on a sufficiently broad area to allow meaningful analyses.

5. That significant interaction occur between operational planners and managers and the policy analysis group. This is key to keeping analysis in the realm of the real world.

This policy analysis group concept would be the ideal vehicle for capturing the benefits of ISEM. Clearly ISEM would be the tool that would satisfy item (3) above. Further, the ISEM concept is based upon the concept underlying (1) and (2). There is little doubt that proper institutional arrangements could be made so that (4) and (5) could be satisfied.

As envisioned here, the "Manpower and Personnel System Policy Analysis Group" would consist of not more than fifteen professional staff drawn from several disciplines. An acceptable group composition from the viewpoint of academic discipline might consist of two labor economists, an econometrician, two computer programmers, an industrial psychologist, two management systems specialists, experts in mathematical programming, someone trained in systems dynamics, and an accountant. At least one-fourth of the group should have had some experience in the manpower career field and one-fourth in personnel. Another one-fourth of the group should have planning experience in the Air Training Command and Recruiting Service.

The group would divide its efforts among four basic tasks. The first would be model development to maintain the descriptive fidelity of the model and to enhance its evaluative capabilities. The second task would be internal system design studies. The final task would be research analysis to evaluate major human resources research proposals.

Ideally, this group would report directly to a high-level Air Force organization. This would conform to item (4) above. Where the group *would geographically reside is a moot point.* The recent trend has been setting up centers of responsibility under the administration of the Air University (such as with the Logistics Management Center, Leadership Management Development Center) under sponsorship of high-level functional managers. This has allowed groups to work in a somewhat less pressured atmosphere than the Pentagon provides. That this is more conducive to deep thinking about long-range issues is obvious. This must, however, be traded against the practical problems of communicating views over long-distance.

While this policy analysis group would be the primary user of the full capabilities of ISEM, the model should be highly accessible to staff planning agencies. It could be used by them for training of system managers, for contingency planning, for decision analysis, and as a baseline design for modifying information flows within the AFMPS.

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